Topography and spatial fascicular arrangement of the human inferior alveolar nerve

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Topography and spatial fascicular arrangement of the human inferior alveolar nerve

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또한 바쁘신 중에도 많은 조언과 질책으로 이끌어주신 정한성 교수님, 고기석 교수님, 김흥중 교수님, 허경석 교수님께도 진심으로 감사드립니다.

논문의 처음부터 끝까지 하나하나 챙겨주신 허미선 선생님께 고마운 마음을 전하며, 구강생물학 교실원 여러분의 도움도 잊을 수 없습니다.

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언제나 묵묵히 모든 기쁨과 슬픔을 함께하는 사랑하는 아내 지영, 그리고 우리집 기둥인 아들 경민, 이제 막 걸음마를 시작하는 딸 수민에게도 아빠로서의 미안함과 고마움을 전합니다.

이 연구 결과가 작게나마 이 시대의 치의학 발전에 기여하고, 치의학을 연구하는 후학들에게 도움 되는 귀중한 자료가 되기를 기원합니다.

2008년 12월

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Topography and spatial fascicular arrangement of the human inferior alveolar nerve

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The inferior alveolar nerve (IAN) is a sensory nerve that innervates the mandibular teeth, periodontium, buccal and lingual mucosa, and lower lip. It runs downward and forward within the mandibular canal (MC), generally below the apices of the teeth. IAN can be damaged during dental surgery, retromolar surgical procedures such as the third molar extraction, osteotomy nearer to the mental foramen obviously risks the IAN. The fascicular organization of the IAN provides critical information for the estimation of damage to portions of the IAN based on patient symptoms, or conversely to evaluate the symptoms resulting from injury to a known part of the IAN. The aim of this study was to clarify the patterns and variations in the course of the IAN by topographic examination followed by detailed dissection and micro computed tomography (micro-CT) analysis. The fascicular composition and organization of the IAN were also determined to confirm the micro-architecture of the IAN bundles into each of the mandibular teeth and periodontium, including the composition of the MN. IAN within the MC was examined in 30 hemifaces (19 males, 11 females) of embalmed Korean cadavers (mean age 66.8 years, range 48~87 years).

The course of the IAN was classified into three types : Type Ⅰ: IAN in a single MC. This type was the most frequently observed, being seen in 21 outof 30 specimens (70.0%), Type Ⅱ: IAN in a single MC with an accessory canal. This type was found in 7 out of 30 specimens (23.3%), Type Ⅲ: IANs in a bifid MC. This type was found in only 2 of the 30 specimens (6.7%). Retromolar branches were observed in 13 out of the 30 specimens (43.3%). On micro-CT image, the mean diameter of the MC before it divides into the accessory and retromolar canals was 4.1±0.9 mm and 4.1±0.7 mm, respectively. The mean diameter of the accessory and retromolar canals on micro-CT image was 1.0±0.5 mm and 1.1±0.3 mm, respectively. The mean diameter of the MC in the mandibular first, second, and third molar regions was 3.3±0.8 mm, 3.1±0.6 mm, and 3.3±0.8 mm, respectively. The IAA is located inferobuccally against the IAN in the mandibular foramen, travelsto the lingual aspect, and then is located superior and lingual to the IAN within the MC. This pattern was the most frequently observed, being seen in 10 out of 17 dissections (58.8%). The somatotopic arrangement of the IAN was categorized according to the nerve fascicles innervating each tooth. In all of 15 cases of nerve-fascicle separation, the nerve fascicles located at the superior buccal portion of the IAN within the MC innervated the mandibular second and third molars. The nerve fascicles innervating the first molar were classified into two categories: (1) those running in the superior buccal portion of IAN within the MC and innervating the first molar (10 out of 15 specimens, 66.7%), and (2) those running in the superior portion of the IAN and innervating the first molar (5 out of 15 specimens, 33.3%). A nerve branch innervating the second premolar was observed for two categories of nerve fascicles running in: (1) the superior portion of the IAN (13 cases, 86.7%) and (2) the superior buccal portion of the IAN (2 cases, 13.3%). The nerve fascicles innervating the first premolar were classified into four types, with the nerve fascicles running in (1) the superior

lingual portion (nine cases, 60.0%), (2) the superior buccal portion (three cases, 20.0%), (3) inferior lingual portion (two cases, 13.3%), and (4) the superior portion of the IAN (one case, 6.7%). The courses of the nerve fascicles innervating the mandibular anterior teeth (central, lateral incisors, and canine) could be divided into six categories. The most common patterns of them were that (1) the superior lingual portion of the IAN within the posterior MC and the lingual portion within the anterior MC (five cases, 33.3%), (2) the superior and inferior lingual portions of the IAN within the posterior MC, and then in the lingual portion within the anterior MC after merging (five cases, 33.3%). The MN traveled mainly within the IAN and contained nerve fascicles running in the buccal portion throughout the MC.

Key words : inferior alveolar nerve, dental nerve, mental nerve, nerve fascicles, mandibular canal, inferior alveolar artery

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Ⅰ. INTRODUCTION

The inferior alveolar nerve (IAN) is a sensory nerve that innervates the mandibular teeth, periodontium, buccal and lingual mucosa, and lower lip. It runs downward and forward within the mandibular canal (MC), generally below the apices of the teeth (Standring et al., 2005). The complete division of the IAN into the dental nerve and the mental nerve (MN) is easily distinguished (Hu et al., 2007).

There are several ways in which the IAN can be damaged during dental surgery for example, it might be affected by perforation of the MC during drilling, positioning of an implant fixture too close to the canal, with subsequent formation of an adjacent hematoma that presses against the nerve, or by damage to a double or supplementary dental canal (Lamas Pelayo et al., 2008). Retromolar surgical procedures such as third-molar extraction are also a common cause of IAN damage (Genú and Vasconcelos, 2008), as is osteotomy near to the mental foramen (Hwang et al., 2005).

Injury to the IAN during implant placement is a serious complication (Burstein et al., 2008). The results of nerve damage range from mild paresthesia to complete anesthesia or disabling dysesthesia (Worthington, 2004). Sensory disturbances produced following implant placement in the mandible are the result of injury to either the IAN or the MN (Bartling et al., 1999).

Little attention has been paid to the detailed fascicular anatomy of the human IAN, although variation of the fascicular arrangement of this nerve is important. Rather than plexiform, the fascicles of peripheral nerves are arranged mainly in a cable-like fashion, indicating a high degree of somatic organization. Each fascicle of the peripheral nerve contains motor or sensory fibers innervating very specific areas of the skin or specific muscles (Stewart, 2003). Indeed, partial focal nerve lesions can produce restricted clinical deficits. This fascicular pattern is also one of the most important components of a nerve that is responsible for the achievement of a successful functional result during a microsurgical reconstruction (Güerrissi and Miranda, 2007).

The inferior alveolar artery (IAA), one of three arteries that supply the mandible, is also important in dental-implant surgery. The loss of neural blood supply or the development of an intraneural hematoma might cause IAN neuropathy (Flanagan, 2003). The relationship between the nerve, artery, and vein at the mandibular foramen has clinical significance during IAN block anesthesia (Wadu et al., 1997). It is thus important to understand this relationship and the topography of the neurovascular bundle within the MC to provide references for this procedure.

The aim of this study was to clarify the patterns and variations in the course of the IAN by topographic examination followed by detailed dissection and micro computed tomography (micro-CT) analysis. The fascicular composition and organization of the IAN were also determined to confirm the micro-architecture of the IAN bundles into each of the mandibular teeth and periodontium, including the composition of the MN. The findings of this study will provide critical information for the estimation of damage to portions of the IAN based on patient symptoms, or conversely to evaluate the symptoms resulting from injury to a known part of the IAN.

Ⅱ. MATERIALS & METHODS

The IAN within the MC was examined in 30 hemifaces (19 males, 11 females) of embalmed Korean cadavers (mean age 66.8 years, range 48 - 87 years). Latex (Neoprene, Lot No. 307L146, DuPont, France) with a red coloring agent (Colorant Universel, Castorama, France) was injected into all of the specimens through the common carotid artery to enable observation of the topographic between the IAN and IAA within the MC.

A. Microdissection of the inferior alveolar nerve

Prior to 17 of the dissections, the specimens were decalcified in 40 l of decalcification solution for 2 weeks. The decalcification solution was prepared with 7 g of aluminum chloride hexahydrate ($Al_2Cl_36H_2O$), 8.5 ml of 30% hydrochloric acid, and 8.5 ml of 100% formic acid, which was then diluted to 100 ml with distilled water. After decalcification, the specimens were neutralized for 2 - 3 days in a neutralization solution prepared from 5 g of sodium sulfate in 100 ml of distilled water. A detailed dissection on the lingual side of the mandible was performed in these 17 decalcified specimens, with the aid of a surgical microscope (OPMI-FC, Carl Zeiss Co., Germany). Extreme care was taken not to damage the dental branches of IAN after opening the MC. After exposing the IAN and its branches, the specimens were immersed in guanidine HCl (0.2 M) for 2 weeks and then treated with ultrasonic cleaner for 1 h to soften the connective tissue around the nerve bundles. The processed IAN and its branches were dissected, again with the aid of a surgical microscope, carefully removing the connective tissue to trace the nerve fascicles innervating each tooth and to confirm the composition and organization of the IAN.

The course of the IAN was classified into three types as follows (Fig. 1):

Type Ⅰ: IAN in a single MC.

Type Ⅱ: IAN in a single MC with an accessory canal.

Type Ⅲ: IANs in a bifid MC.

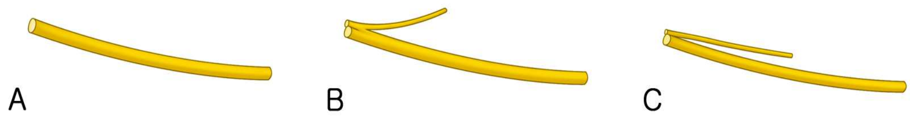

Fig. 1. The course of the inferior alveolar nerve (IAN). (A) IAN in a single mandibular canal (MC). (B) IAN in a single MC with an accessory canal. (C) IANs in a bifid MC.

The relationship between the IAN and the IAA was classified into three types according to the location of the IAA relative to the IAN within the mandibular foramen and MC as follows (Fig. 2):

Type A: the IAA is located inferobuccally against the IAN in the mandibular foramen, travels to the lingual aspect, and then is located superior and lingual to the IAN within the MC.

Type B: the IAA is located superobuccally in the mandibular foramen and travels toward the superior and lingual aspect to the IAN.

Type C: the IAA is located lingually to the IAN within the MC throughout the canal.

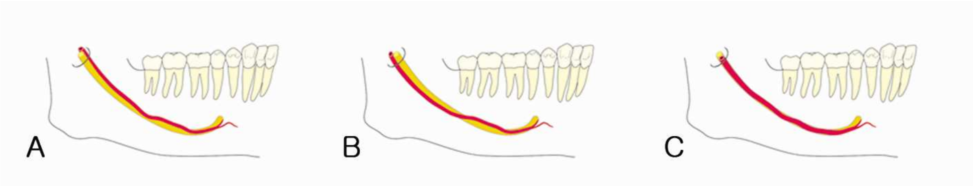

Fig. 2. The relationship between the inferior alveolar nerve (IAN) and the inferior alvolar artery (IAA). (A) The IAA is located inferobuccally against the IAN in the mandibular foramen, travels to the lingual aspect, and then is located superior and lingual to the IAN within the mandibular canal (MC). (B) The IAA is located superobuccally in the mandibular foramen and travels toward the superior and lingual aspect to the IAN. (C) The IAA is located lingually to the IAN within the MC throughout the canal.

B. Taking Micro-CT of mandibular canal

Specimens of 13 mandibles were scanned using a micro-CT system (Skyscan 1072, Skyscan Co., Antwerp, Belgium). The specimens were placed on the holder between the X-ray source and the CCD camera, and were rotated around the vertical axis at intervals of 0.9° for 180°, while keeping it in the field of view, thereby producing 200 projections. The beam was projected onto a phosphorus screen, which converted the X-rays into visible light that was detected by a CCD camera. The data were then digitized by a frame-grabber and transmitted to a computer with tomographic reconstruction software. Cross-sectional 1968×1968-pixel images were created. A 3D structural image with voxels 35×35×35 μm in size was created from the 2D images using a 3D reconstruction program (Lucion, Cybermed Co., Korea). After reconstructing the images, the mandible was sectioned arbitrarily to observe the presence and configuration of accessory MC and retromolar canal.

Measurements were also made of the diameters of the MC before it divides into the accessory canals or retromolar canals, the accessory and retromolar canals themselves, and the MC at the mandibular first, second, and third molar regions, using the 3D reconstruction program.

All photographs and diagrams in this article are of structures viewed from the left and lingual side of the face.

Ⅲ. RESULTS

The course of the IAN was classified into three types. Type Ⅰ which IAN in a single MC was the most frequently observed, being seen in 21 out of 30 specimens (70.0%) - 11 out of 17 dissections (64.7%) and 10 out of 13 micro-CT images (76.9%). TypeⅡ which IAN in a single MC with an accessory canal was found in 7 out of 30 specimens (23.3%) - 4 out of 17 dissections (23.5%) and, 3 out of 13 micro-CT images (23.1%). TypeⅢ which IANs in a bifid MC was found in only 2 of the 30 specimens (6.7%), and both were from dissected specimens (Fig. 3).

The accessory canals divided below the mandibular foramen, running close to the root apices of the mandibular molars. The bifid MCs ran parallel to each other, and the molar dental branches arose from the upper canal, which was thinner than the lower major MC.

Retromolar branches were observed in 13 out of the 30 specimens (43.3%): 10 out of 17 dissections (58.8%) and 3 out of 13 micro-CT images (23.1%). These branches, which were observed more than twice as often in dissections as in micro-CT images, usually ascended a little lingually, finally innervatingthe internal oblique ridge (Fig. 4).

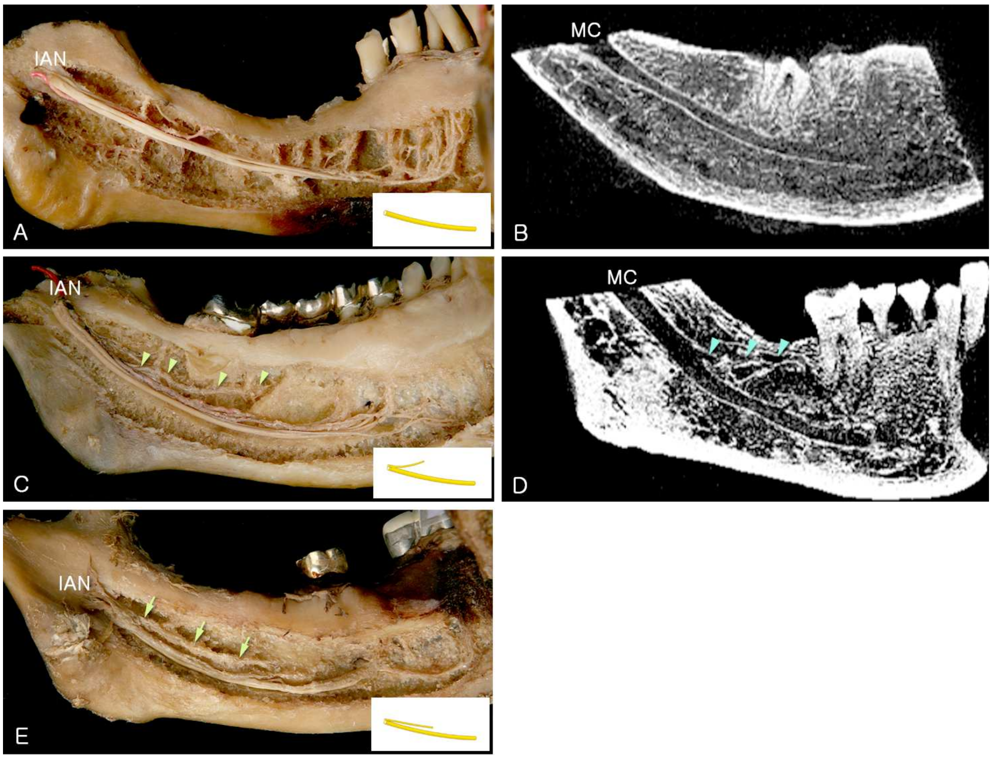

Fig. 3. Patterns of the course of the inferior alveolar nerve (IAN) from the posterior view of the mandible. (A) IAN of a single mandibular canal (MC) (dissection). (B) Sectional image of a reconstruction of the mandible to show the IAN of a single MC (micro-CT image; thickness 35 μm). (C) IAN of a single MC with an accessory canal (arrowhead) innervating the retromolar area, and the second and third molars (dissection). (D) Sectional image of a reconstruction of the mandible to show the IAN of a single MC with an accessory canal (arrowhead) (micro-CT image; thickness 35 μm). (E) IAN of bifid MCs. Upper canal (arrow) was thinner than the lower major MC (dissection).

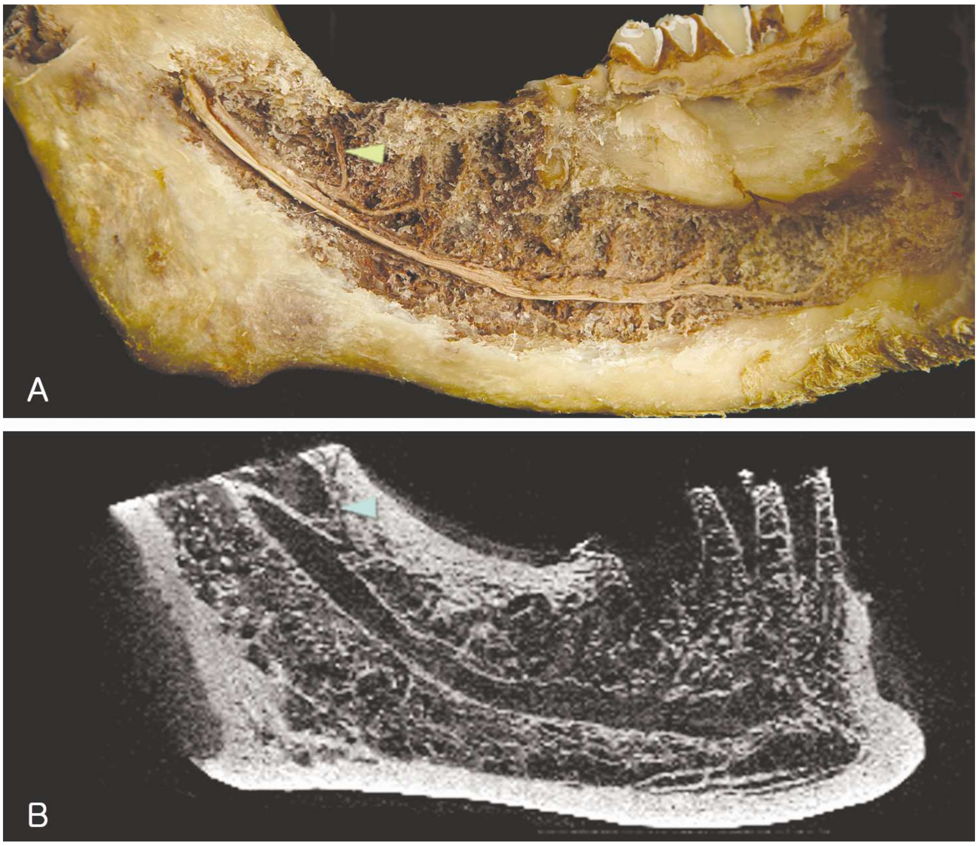

Fig. 4. The nerve branch innervating the retromolar area. (A) The retromolar branch (arrowhead) ascending a little lingually to innervate the retromolar area (dissection). (B) Sectional image of a reconstruction of the mandible to show the retromolar canal (arrowhead).

On micro-CT image, the mean diameter of the MC before it divides into the accessory and retromolar canals was 4.1±0.9 mm (range 3.5∼5.1 mm) and 4.1±0.7 mm (range 3.7∼4.9 mm), respectively. The mean diameter of the accessory and retromolar canals on micro-CT image was 1.0±0.5 mm (range 0.6∼1.6 mm) and 1.1±0.3 mm (range 0.8∼1.3 mm), respectively (Tables 1 and 2). The mean diameter of the MC in the mandibular first, second, and third molar regions was 3.3±0.8 mm (range 2.1∼4.9 mm), 3.1±0.6 mm (range 2.4∼4.3 mm), and 3.3±0.8 mm (range 2.2∼5.0 mm), respectively. The MC thus showed a tendency to maintain its diameter in the molar regions (Table 3).

Table 1. Diameters of the accessory canal unit: mm, n=3

Diameter	MC before dividing	accessory canal
Mean	4.1	1.0
SD	0.9	0.5
Maximum	5.1	1.6
Minimum	3.5	0.6

MC: mandibular canal, SD: standard deviation.

Table 2. Diameters of the retromolar canal unit: mm, n=3

Diameter	MC before dividing	retromolar canal
Mean	4.1	1.1
SD	0.7	0.3
Maximum	4.9	1.3
Minimum	3.7	0.8

MC: mandibular canal, SD: standard deviation.

Table 3. Diameters of the mandibular canal with a reference to the mandibular molar regions unit: mm, n=3

Diameter	1st Molar	2nd Molar	3rd Molar
Diameter of MC			
Mean	3.3	3.1	3.3
SD	0.8	0.6	0.8
Maximum	4.9	4.3	5.0
Minimum	2.1	2.4	2.2

MC: mandibular canal, SD: standard deviation.

The relationship between the IAN and the IAA was classified into three types according to the location of the IAA relative to the IAN within the mandibular foramen and MC (Fig. 5):

Type A which the IAA is located inferobuccally against the IAN in the mandibular foramen, traveled to the lingual aspect, and then is located superior and lingual to the IAN within the MC. This pattern was the most frequently observed, being seen in 10 out of 17 dissections (58.8%). Type B which the IAA is located superobuccally in the mandibular foramen, traveled toward the superior and lingual aspect to the IAN. This pattern was observed in 6 out of 17 dissections (35.3%). Type C which the IAA is located lingually in the mandibular foramen, traveled lingually to the IAN throughout the MC. This pattern was observed in only one case, and that was one of the cases of a bifid MC.

In all specimens, one arterial branch left the IAA after entering the mandibular foramen. In cases where the IAA was located inferobuccally within the mandibular foramen (type A), the arterial branch ascended superobuccally against the IAN, usually to supply the mandibular molars. In cases wherethe IAA ran superobuccally within the mandibular foramen (type B), the arterial branch traveled parallel to the main IAA the IAA and its branch then ran lingually to those IAN nerve fascicles that usually innervate the mandibular molars (Fig. 6). Where there was an accessory canal and a bifid MC, the nerve fascicles comprising the superior buccal aspect of the IAN were located within these canals (types Ⅱ and Ⅲ) instead of the single MC (type I).

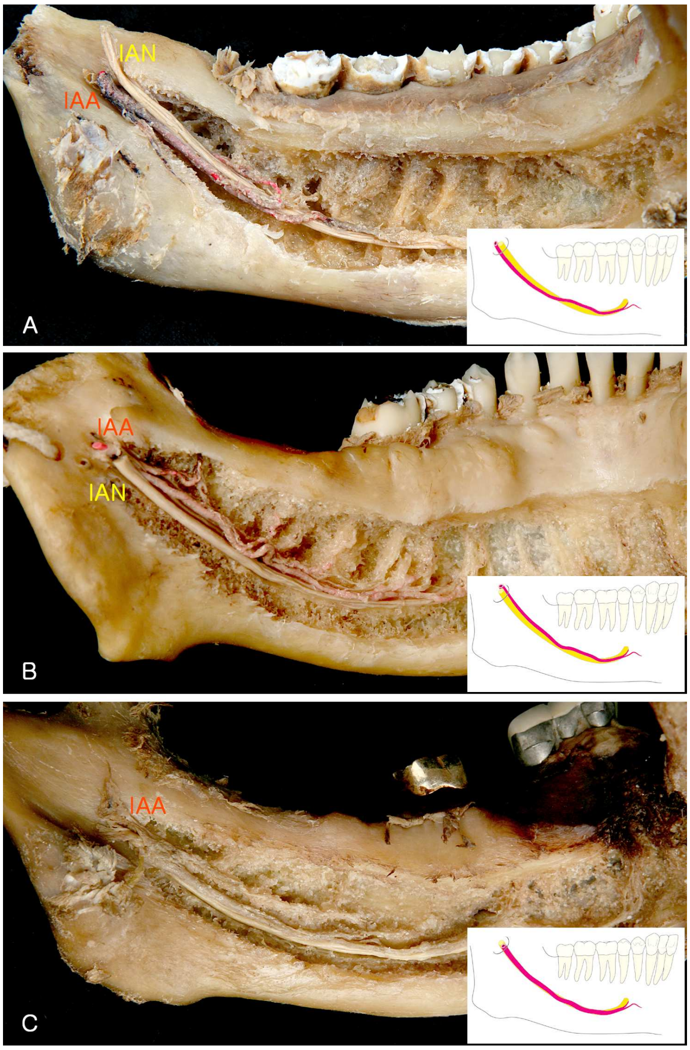

Fig. 5. Spatial relationships between inferior alveolar nerve (IAN) and inferioraleolar artery (IAA). IAA located (A) inferobuccally, (B) superobuccally, and (C) lingually, in the mandibular foramen, and traveling toward the superior and lingual to IAN throughout the canal. Insets (A - C): diagrammatic representation of the path of the IAN (yellow) and IAA (red) seen in the main picture.

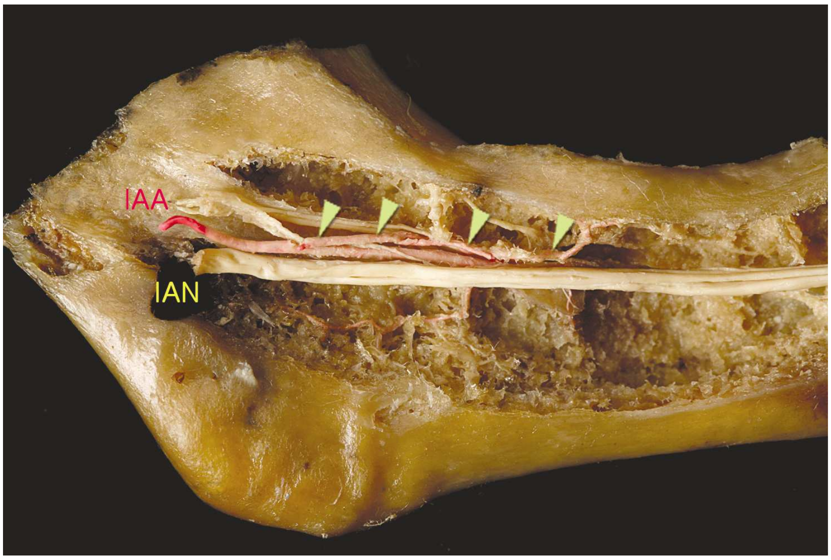

Fig. 6. The arterial branch (arrowhead) of the inferior alveolar artery (IAA) traveling parallel to the main IAA. The IAA and its branch then run along the lingual aspect to some of the inferior alveolar nerve (IAN) nerve fascicles, usually those innervating the mandibular molars.

The spatial fascicular arrangement of the IAN took various forms. The somatotopic arrangement of the IAN was categorized according to the nerve fascicles innervating each tooth. In all of 15 cases of nerve-fascicle separation, the nerve fascicles located at the superior buccal portion of the IAN within the MC innervated the mandibular second and third molars (Fig. 7A, Fig. 8). When present, the retromolar branch also arose from the superior buccal nerve fascicles of the IAN. The nerve fascicles innervating the first molar were classified into two categories (Fig. 7B): (1) those running in the superior buccal portion of IAN within the MC and innervating the first molar (10 out of 15 specimens, 66.7%), and (2) those running in the superior portion of the IAN and innervating the first molar (5 out of 15 specimens, 33.3%). A nerve branch innervating the second premolar was observed for two categories of nerve fascicles running in (Fig. 7C): (1) the superior portion of the IAN (13 cases, 86.7%) and (2) the superior buccal portion of the IAN (2 cases, 13.3%). The nerve fascicles innervating the first premolar were classified into four types, with the nerve fascicles running in (1) the superior lingual portion (nine cases, 60.0%), (2) the superior buccal portion (three cases, 20.0%), (3) inferior lingual portions (two cases, 13.3%), and (4) the superior portion of the IAN (one case, 6.7%) (Fig. 7D).

The courses of the nerve fascicles innervating the mandibular anterior teeth (central, lateral incisors, and canine) could be divided into six categories - nerve fascicles running in (Fig. 7E):

1. The superior lingual portion of the IAN within the posterior MC and the lingual portions within the anterior MC (five cases, 33.3%, Fig. 9).

2. The superior and inferior lingual portions of the IAN within the posterior MC, and then in the lingual portion within the anterior MC after merging (five cases, 33.3%).

3. The superior lingual portion of the IAN throughout the MC (two cases, 13.3%) (Fig. 10).

4. The inferior lingual portion of the IAN throughout the MC (one case, 6.7%).

5. The inferior portion of the IAN, receiving the nerve fascicles from the inferior lingual and inferior buccal aspects within the posterior MC, and then in the inferior lingual portion of the IAN within the anterior MC (one case, 6.7%).

6. The lingual and buccal portions of the IAN within the posterior MC, and then in the lingual portions of the IAN within the anterior MC (one case, 6.7%).

The MN traveled mainly within the IAN and contained nerve fascicles running in the buccal portion throughout the MC.

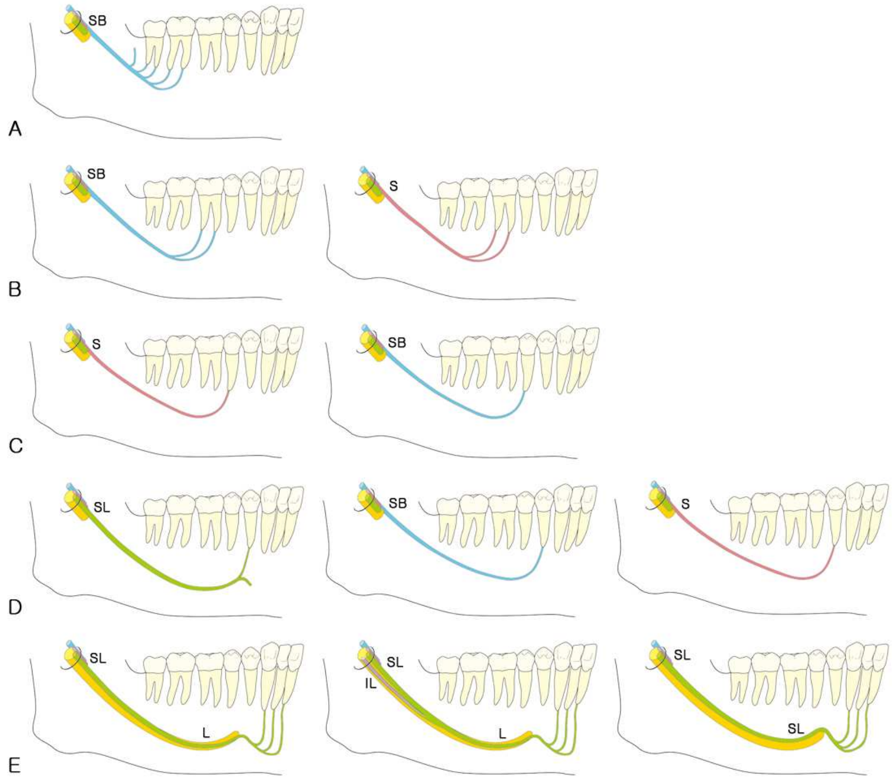

Fig. 7. Schematic illustrations of the innervation patterns of the inferior alveolar nerve (IAN) innervating the teeth. (A) The superior buccal fascicles (SB) innervating the second and third molars, and the retromolar area. (B) The superior buccal portion (SB) and superior portion (S) of the IAN innervating the first molar. (C) The superior portion (S) and superior buccal portion (SB) of the IAN innervating the second premolar. (D) The superior lingual portion (SL), superior buccal portion (SB), and superior portion (S) of the IAN innervating to the first premolar. (E) The superior lingual portion (SL) within the posterior mandibular canal (MC) and the lingual portion (L) within the anterior MC, the superior and inferior lingual portions (SL, IL) of the IAN within the posterior MC and the lingual portion (L) within the anterior MC, and the superior lingual portion (SL) throughout the MC.

Fig. 8. The inferior alveolar nerve (IAN) fascicles innervating the second and third molars. The superior buccal portion (SB) of the inferior alveolar nerve (IAN) innervating the second and third molars (The other fascicles of the IAN are pulled inferiorly to show the superior buccal fascicles of the IAN).

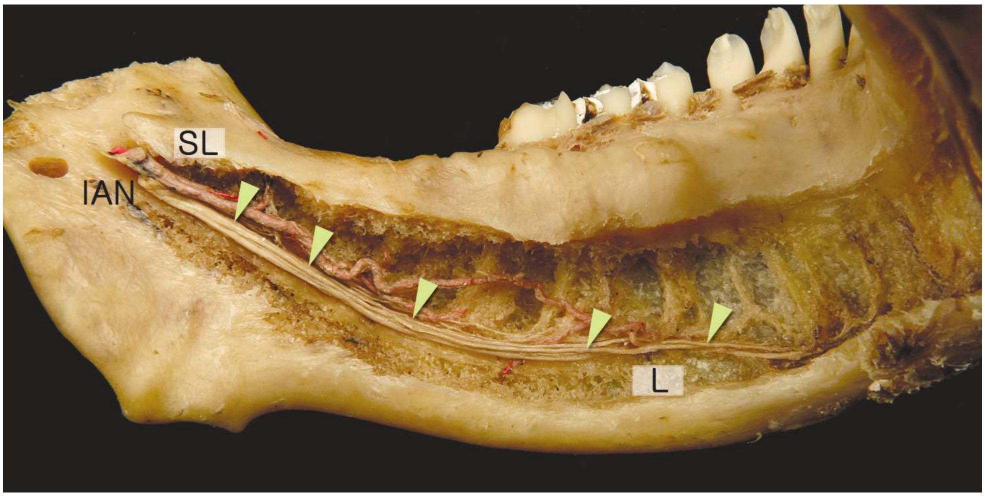

Fig. 9. The inferior alveolar nerve (IAN) fascicles innervating anterior teeth. The superior lingual portion (SL) of the inferior alveolar nerve (IAN) within the posterior mandibular canal and the lingual portion (L) within the anterior mandibular canal, innervating anterior teeth (The inferior alveolar artery is pulled superiorly to show the IAN).

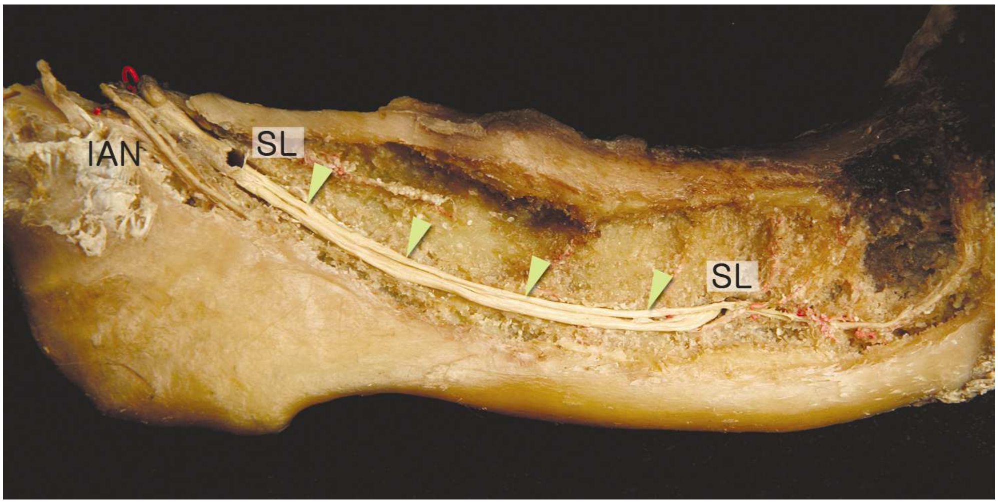

Fig. 10. The superior lingual portion (SL) of the inferior alveolar nerve (IAN) throughout the mandibular canal, innervating anterior teeth.

Ⅳ. DISCUSSION

Knowledge of the anatomy of the MC and its related structures can provide information regarding the degree and extent of damage to the IAN resulting from both direct and indirect injury. With regard to direct injury, MC configuration and variations there can be risk factors in surgical procedures involving the mandible, such as extraction of an impacted third molar, dental-implant treatment, and ramus osteotomy (Naitoh et al., 2007).

The intraosseous course of the IAN has been described in several studies of the configuration of the MC and the branching patterns of the IAN (Carter and Keen, 1971; Anderson et al., 1991, Kieser et al., 2004); the presence of a bifid canal has been reported to occur less than 1% (Grover and Lorton, 1983 Wyatt, 1996). In the present study, accessory and bifid canals were found in 30.0% of cases by dissection and micro-CT observation, a much higher frequency of occurrence than determined in those previous reports. We found that an accessory canal and bifid MCs usually run below the roots of the mandibular molars, and give off nerve branches to the first and second molars. Hence, the possibility of the presence of an accessory canal and a bifid MC should be recognized during implant surgical procedures performed prior to implant fixture placement in the molar region.

Indirect damage following surgical procedures can cause altered sensation. Placement of an implant fixture too close to the MC can impose a mechanical stress on the structures of the MC, resulting in impairments in nerve function (Sammartino et al., 2008). It has been suggested that a minimum distance between the implant fixture and the MC is needed to avoid such nerve damage (Wismeijer and van Wass, 1997; Greenstein and Tarnow, 2006).

Damage to the inferior alveolar vessels within the MC by either direct or indirect injury results in hemorrhage, which can in turn compress the underlying IAN and MN (Kalpidis and Setayesh, 2004). There are discrepancies between previous reports of the relationship between the IAN and IAA. Li et al. (2001) reported that the blood vessel is located superiorly to the IAN within the MC. Zoud and Foran (1993) reported that the IAN and IAA form an intertwined plexus throughout the MC. Wadu (1997) stated that the nerve lies between the blood vessels and the bone, and that the vein is anterior to the artery at the mandibular foramen. However, to our knowledge there has been no study on the classification of the topography of the relationship between the IAN and IAA.

In the present study, we classified the topography of the IAN and IAA into three types, and found that in most cases the arterial branch is located at the superior buccal aspect of the MC in the mandibular molar and retromolar regions. The anatomical relationship between the IAN and IAA found in the present study is similar to that described in other studies of the anterior MC. The IAA is thus more vulnerable to instrument-induced damage than is the IAN during implant surgery.

If the sensory loss resulting from the damage to the IAN reveals the extent of the paresthetic lesion, similar to the case in spinal cord segmental lesions, detailed knowledge of the topography of the IAN could provide a useful basic map with which to interpret the symptoms of a nerve injury, and will aid in repair of the injured nerve. In the present study, the fascicular somatotopic arrangement of IAN and its branches exhibited an array of patterns and variations. However, there was some degree of consistency. The most common patterns of nerve fascicle innervation to the mandibular teeth could be grossly classified into three: (1) the superior buccal portion of the IAN innervating the molars, (2) the superior portion innervating the premolars, and (3) the superior lingual portion or the superior lingual and inferior lingual portions in the posterior MC and the lingual portions in the anterior MC innervating the incisors and canine. The buccal two-thirds portion of the IAN was composed of the MN innervating the lower lip, the skin of the chin, and the vestibular gingiva (Fig. 11). The innervating patterns of nerve fascicles described in the present study are similar to those detailed previously for the prenatal MC and innervation to the deciduous dentition by Cávex-Lomeli et al. (1996). These authors stated that the IAN presumably exists in the mandible as three individual nerve paths that ariseat different stages of development. The prenatal nerve paths of the IAN with three MCs might still be considerably preserved, thus affecting the organization of the IAN nerve fascicles and its branches in the adult.

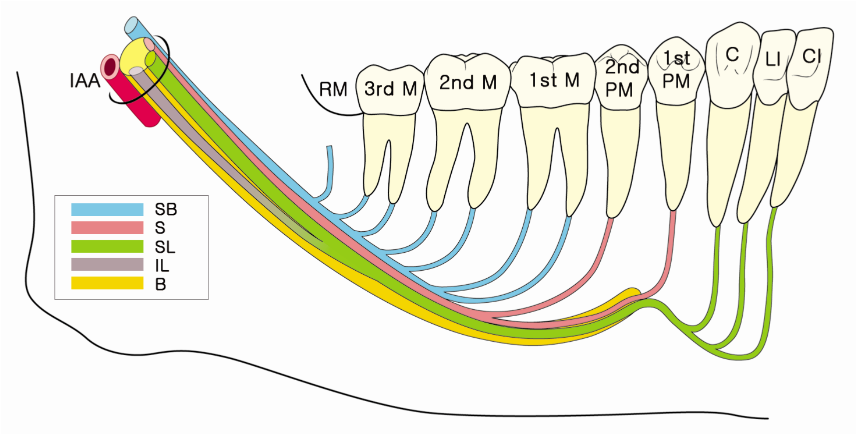

Fig. 11. The most common spatial fascicular arrangements of the inferior alveolar nerve (IAN). Superior buccal portion (SB) of the IAN innervating the first molar (1st M), second molar (2nd M), third molar (3rd M), and the retromolar area (RM), the superior portion (S) innervating the first premolar (1st PM) and second premolar (2nd PM), the superior lingual portion (SL) or superior lingual (SL) and inferior lingual (IL) portions in the posterior mandibular canal, and the lingual portions (L) in the anterior mandibular canal, innervating the central incisor (CI), lateral incisor (LI), and canine (C). The buccal (B) two-thirds portion of the IAN comprised the mental nerve.

Ⅴ. CONCLUSION

The conclusions of this study are as follows.

1. The most frequent type of IAN was single canal in 70.0%. The accessory mandibular canal was 23.3%, and bifid canal was 6.7%. The accessory canal and bifid MCs usually ran below the roots of mandibular molars, and gave off the nerve branches to the 1st and 2nd molar.

2. Retromolar branches were observed in 13 out of the 30 specimens (43.3%): 10 out of 17 dissections (58.8%) and 3 out of 13 micro-CT images (23.1%). These branches, which were observed more than twice as often in dissections as in micro-CT images, usually ascended a little lingually, finally innervating the internal oblique ridge.

3. On micro-CT image, the mean diameter of the MC before it divides into the accessory and retromolar canals was 4.1±0.9 mm and 4.1±0.7 mm, respectively. The mean diameter of the accessory and retromolar canals on micro-CT image was 1.0±0.5 mm and 1.1±0.3 mm, respectively. The mean diameter of the MC in the mandibular first, second, and third molar regions was 3.3±0.8 mm, 3.1±0.6 mm, and 3.3±0.8 mm, respectively. The MC thus showed a tendency to maintain its diameter in the molar regions.

4. The IAA is located inferobuccally against the IAN in the mandibular foramen, travels to the lingual aspect, and then is located superior and lingual to the IAN within the MC. This pattern was the most frequently observed, being seen in 10 out of 17 dissections (58.8%).

5. The most common patterns of nerve fascicle innervation to the mandibular teeth could begrossly classified into three: (1) the superior buccal portion of the IAN innervating the molars, (2) the superior portion innervating the premolars, and (3) the superior lingual portion or the superior lingual and inferior lingual portions in the posterior MC and the lingual portions in the anterior MC innervating the incisors and canine. The buccal two-thirds portion of the IAN was composed of the MN innervating the lower lip, the skin of the chin, and the vestibular gingiva.

6. Using our results we can forecast the degree, location, and extent of nerve damage within the MC according to presenting symptoms:

· Sensory loss of the mandibular incisors and canine can result from injury to the superior lingual fascicles and inferior lingual fascicles of the IAN in the molar and retromolar areas, or from the injury to the lingual fascicles of the IAN within the anterior MC.

· Sensory loss of the molars can result from injury to the superior buccal fascicles of the IAN in the molar and retromolar areas.

· Sensory loss of the premolars can result from injury to the superior fascicles of the IAN throughout the MC.

· Sensory loss of the lower lip and chin region can result from damage to the buccal two-thirds of the fascicles of the IAN throughout the MC.

Conversely, it is possible to evaluate nerve symptoms from the injured portion of the MC during implant surgery, genioplasty, and other surgical procedures of the mandible.

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Abstract (in korean)

아래이틀신경의 국소해부와 신경다발배열의 특징

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김 현 철

아래이틀신경은 감각신경으로, 턱뼈관을 통해 아래앞쪽으로 달리며, 아래턱 큰어금니, 작은어금니, 송곳니, 앞니의 치아뿌리끝을 지나면서 치아속질에 분포하는 치아가지와 턱끝부위 피부에 분포하는 턱끝신경을 낸다. 아래이틀신경 신경다발의 삼차원적 위치배열은 임플란트 시술, 턱끝성형술, 또는 아래턱뼈자름술시 아래이틀신경이 손상되었을 때 손상부위와 범위를 예측하는데 중요한 해부학적 자료가 될 수 있다. 따라서 이 연구의 목적은 아래이틀신경의 형태와 변이를 관찰하고, 각 치아가지의 신경다발 배열양상을 삼차원적으로 재구성하는데 있다. 또한 아래이틀신경과 혈관과의 위치관계를 관찰하여 턱뼈관의 부위별 손상시 출혈을 예측하는데 있다. 재료는 한국 성인시신 아래턱뼈 30 쪽 (남자 19 쪽, 여자 11 쪽, 평균나이 66.8살)을 사용하였다. 그 중 17 쪽은 탈회를 한 후, 혀쪽에서 턱뼈관을 열어 아래이틀신경과 그 가지들을 해부하였다. 그리고 Guanidine-HCL 0.2 M에 2주 이상 담구어 신경바깥막 (epineurium)을 부드럽게 한 뒤, 수술현미경을 사용하여 신경다발을 분리하였고 각 치아가지를 구성하는 신경다발의 위치와 경로를 추적하였다. 나머지 13 쪽은 Micro-CT system (Skyscan 1072, Skyscan, Antwerp, Belgium)을 이용하여 아래턱뼈의 연속적인 관상단면 이미지를 만들었고, 이 단면 이미지들을 재구성하기 위하여 3차원재구성프로그램 (Lucion, Cybermed, Korea)을 이용하여 3차원 영상을 만들었다. 이 3차원 영상에서 턱뼈관의 경로가 보이도록 단면을 잘라 턱뼈관의 형태와 그 가지들을 확인하고 지름을 계측하였다.

아래이틀신경의 경로는 턱뼈구멍에서 아래앞쪽으로 내려와 앞쪽으로 주행하다 턱끝구멍을 향하여 약간 올라갔다. 턱끝신경이 되지 않은 신경다발들은 턱끝구멍부위에서 아래쪽으로 꺾여서 아래턱뼈 아래모서리부위까지 내려갔다가 위쪽으로 다시 올라와 안쪽앞니의 치아가지로 끝났다. 치아가지의 분포방향은 둘째작은어금니와 첫째, 둘째, 셋째큰어금니의 경우 가쪽에서 안쪽으로 비스듬하게 올라가 치아에 분포하였고, 안쪽과 가쪽앞니, 송곳니, 첫째작은어금니의 경우는 치아가지가 거의 수직으로 올라가 분포하였다.

아래이틀신경의 형태는 아래이틀신경줄기에서 치아가지가 직접 나오는 경우, 아래이틀신경에서 덧가지가 나오는 경우, 아래이틀신경이 두 갈래로 갈라져 평행하게 달리는 경우인 세 가지 유형으로 분류하였다. 아래이틀신경줄기에서 치아가지가 직접 나오는 경우는 30 쪽 중 21 쪽 (70.0%)으로 가장 많이 관찰되었다. 아래이틀신경에서 덧가지가 나오는 형태는 7 쪽 (23.3%)이 있었다. 아래이틀신경이 두 갈래인 경우는 2 예 (6.7%)가 있었다. 어금니뒤가지는 30 쪽 중 13 쪽 (43.3%)에서 관찰되었다. 어금니뒤가지는 주로 안쪽빗선부위에 분포하였다. Micro-CT에서 덧턱뼈관 (accessory mandibular canal)과 어금니뒤관 (retromolar canal)이 갈라져 나오기 전의 턱뼈관의 평균지름은 각각 4.1 mm와 4.1 mm였고, 덧턱뼈관과 어금니뒤관의 평균지름은 1.0 mm와 1.1 mm였다. 턱뼈관내에서 아래이틀신경과 아래이틀동맥의 위치관계는 턱뼈구멍부위에서 아래이틀동맥이 신경줄기의 아래볼쪽 (inferior buccal)에서 시작하여 신경줄기의 혀쪽면으로 올라가 신경줄기의 위쪽과 혀쪽면으로 달리는 경우가 10쪽 (58.8%)으로 가장 많이 관찰되었다. 아래이틀신경의 신경다발배열은 다양한 양상을 나타내었으나, 평균적 신경다발배열 양상은 다음과 같다. 어금니뒤부위, 첫째, 둘째, 셋째큰어금니의 치아가지는 신경줄기에서 위볼쪽 (superior buccal)부분을 달리는 신경다발로 이루어졌다. 첫째와 둘째작은어금니의 치아가지는 신경줄기의 윗부분과 위혀쪽 (superior lingual)부분을 달리는 신경다발로 구성되었다. 안쪽과 가쪽앞니, 송곳니에는 턱뼈관 뒷부분에서 신경줄기의 위혀쪽부분 또는 위혀쪽부분과 아래혀쪽부분을 달리다 합쳐져 턱뼈관 앞부분에서 혀쪽 (lingual)부분을 달리는 신경다발이 분포하였다. 각 치아별 신경분포 유형을 분류하면, 둘째와 셋째큰어금니, 어금니뒤부위에는 신경다발 분리를 한

15 쪽 모든 경우에서 신경줄기의 위볼쪽부분으로 달리는 신경다발이 분포하였다. 첫째큰어금니에는 위볼쪽부분으로 달리는 신경다발이 분포하는 경우는 10 쪽 (66.7%), 신경줄기의 윗부분을 달리는 신경다발이 분포하는 경우는 5 쪽 (33.3%) 이 있었다. 둘째작은어금니에는 신경줄기의 윗부분을 달리는 신경다발이 분포하는 경우는 13 쪽 (86.7%)이었고, 위볼쪽부분을 달리는 신경다발이 분포하는 경우가 2 쪽 (13.3%). 첫째작은어금니에는 신경줄기의 위혀쪽부분을 달리는 신경다발이 분포하는 경우가 9 쪽 (60.0%), 위볼쪽부분으로 달리는 신경다발이 분포하는 경우가 3 예 (20.0%)가 있었다. 안쪽과 가쪽앞니, 송곳니에는 턱뼈관의 뒷부분에서 신경줄기의 위혀쪽부분을 달리다 턱뼈관의 앞부분에서 신경줄기의 혀쪽부분을 지나는 신경다발이 분포하는 경우가 5 쪽 (33.3%)이 있었고, 턱뼈관의 뒷부분에서는 신경줄기의 위혀쪽부분과 아래혀쪽 (inferior lingual)부분에서 시작하여 턱뼈관의 앞부분에서 신경줄기의 혀쪽부분을 지나는 신경다발이 분포하는 경우는 5 쪽 (33.3%) 있었다. 턱끝신경을 이루는 신경다발은 모든 예에서 신경줄기의 볼쪽 2/3 부분을 차지하였다.

핵심되는 말 : 아래이틀신경, 치아가지, 턱끝신경, 신경다발, 턱뼈관. 아래이틀동맥